VEGETATION CLASSIFICATION AND SURVEY

International Association for Vegetation Science (IAVS)

Vegetation Classification and Survey 5: 85–107
doi: 10.3897/VCS.106377

RESEARCH PAPER

Habitat characterization and mapping on the western slopes of Mount Hermon in Lebanon

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5 *"STEPping up Nature Reserves Capacity" Project, United Nations Development Programme, funded by the Ministry of Foreign Affairs and International Cooperation of the Italian Republic through the Italian Agency for Development Cooperation (AICS), Beirut, Lebanon*

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Academic editor: Zdeňka Lososová ♦ **Linguistic editor:** Stephen Bell
Received 14 May 2023 ♦ **Accepted** 8 March 2024 ♦ **Published** 7 June 2024

Abstract

Aims: Lebanon is renowned in the Levant for its distinctive vegetation types with some biodiversity hotspots as Mount Hermon, with rare and endangered endemic plant species. We aim to present the ecological characteristics and spatial distribution of habitat types present on its western slopes through the analysis of plant communities. **Study area:** Mount Hermon, Lebanon. **Methods:** We surveyed 169 plots, each spanning an area of 314 m^2, from 2020 to 2023, in the district of Rashaya, calculated compositional dissimilarity using the Bray–Curtis index, conducted hierarchical clustering analysis using the unweighted pair group method with arithmetic mean (UPGMA), applied the Nonmetric Multidimensional Scaling (NMDS) method to investigate the relationship between species frequency per site and environmental parameters, and identified significant diagnostic species for each group. **Results:** We recorded 383 taxa, including 27 narrow endemics. Ten habitat types are described; three at the oro-Mediterranean level: hedgehog-heaths of *Astragalus echinus* and *Noaea mucronata*, hedgehog-heaths of *Tanacetum densum* and *Astragalus cruentiflorus*, cliffs of *Rosularia sempervivum* subsp. *libanotica*; three at the supra-Mediterranean level: grasslands with *Eryngium glomeratum*, woodlands of *Quercus infectoria*, *Q. coccifera* and *Crataegus azarolus*, evergreen woodlands of *Q. coccifera*; four at the montane level: scree deciduous woodlands of *Prunus korshinskyi* and *Lonicera nummulariifolia*, woodlands of deciduous *P. korshinskyi* and evergreen *Q. coccifera*, shrublands of *Astragalus gummifer*, and deciduous woodlands of *Quercus look* and *Acer monspessulanum* subsp. *microphyllum*. Four environmental variables exhibited significant influences in shaping vegetation composition: elevation, mean annual temperature, slope and northness. **Conclusions:** Five habitats are novelties proposed as sub-types for the national typology. Floristic affinities with Mount Barouk are highlighted. The nature reserve on the western slopes of Mount Hermon encompasses the majority of the identified habitats. The insights from this study and the habitat map are useful for the development of a management plan and conservation measures.

Taxonomic reference: International Plant Names Index (IPNI 2023).

Abbreviations: EUNIS = European Nature Information System; NMDS = nonmetric multidimensional scaling; UPGMA = unweighted pair group method with arithmetic mean; WGS84 = World Geodetic System, 1984.

Keywords

cliffs, endemism, EUNIS, habitat type, hedgehog-heath, vegetation classification, Lebanese national typology, Levant, montane-Mediterranean, *Prunus korshinskyi*, *Quercus look*, oro-Mediterranean

Introduction

Within the eastern Mediterranean, the Levant stands as the junction point between Europe, Africa, and Asia, where three floristic regions meet: the Saharo-Sindian region, the Mediterranean region, and the Irano-Turanian region (Takhtajan 1986). In this biogeographical crossroad, complex biodiversity patterns have emerged (Krupp et al. 2009) and are distributed among the three prominent components of the Levant: the Mediterranean region, the Syro-African Rift, and the Syrian desert. Geographic and geomorphologic features allow the demarcation between the Northern and the Southern Levants. The Northern Levant, extending from the Nur Mountains northward to Galilee southward, is characterised by its distinctive mountainous topography (Abel 1933; Vaumas 1954; Suriano 2013). Mount Lebanon, Anti-Lebanon, and Mount Hermon are located in the Northern Levant, forming the highest ranges across the entire Levant (Vaumas 1954). These ranges have been recognized as regional hotspots of biodiversity within the larger Mediterranean Basin 'macro' hotspot, attributed to their remarkable floristic endemism which accounts for 12% of the total flora (Médail and Quézel 1997, 1999; Myers et al. 2000; Verlaque et al. 2001; Cañadas et al. 2014). At the Lebanese national scale, these mountain ranges are of high-priority conservation value as they have been identified as Important Plant Areas (Bou Dagher-Kharrat et al. 2018) and as Key Biodiversity Areas (El Zein et al. 2018) due to the simultaneous presence of rare and endangered endemic plant species.

Lebanon is renowned for its distinctive vegetation types in the Levant. Since ancient times, dating back to 2600 years BC, its mountains have been recognized for their remarkable and iconic conifer forests, composed of cedar (*Cedrus libani*), fir (*Abies cilicica*), and juniper (*Juniperus excelsa*) (Vaumas 1954; Beals 1965; Mikesell 1969). Nevertheless, other types of vegetation also occur in these mountains, forming unique associations of plant species (Post and Dinsmore 1932; Mouterde 1966, 1970, 1984). Several publications have described the vegetation of Lebanon. The description of the climactic series of vegetation of Lebanon and their spatial distribution constitutes one of the greatest achievements in this discipline for the country (Abi-Saleh 1982; Abi-Saleh and Safi 1988). Complementary efforts have provided detailed information about the phytosociological associations that compose some forest types on the western slopes of the Mount Lebanon range (Chouchani et al. 1975; Barghachoun 1976; de Foucault et al. 2013; Stephan et al. 2019). Recently, a typology of the natural and semi-natural terrestrial habitat types has been developed (El Zein et al. 2022) aligned to the hierarchical structure of the habitat classification of the European Nature Information System (EUNIS) (Davies et al. 2004) to facilitate efforts for conservation across the Mediterranean Basin and in neighboring countries. Moreover, the use of an international classification system improves the recognition of local diversity and natural patrimony.

However, detailed descriptions of the plant communities for each habitat type in Lebanon still require improvement and are continuously developing. The habitat types present on the western slopes of Mount Hermon in Lebanon were partly characterised through the vegetation series (Abi-Saleh and Safi 1988). Part of the area was designated as a nature reserve in December 2020, promoting the undertaking of comprehensive studies to document and conserve the natural patrimony present. The primary objective of our study was to address this knowledge gap and comprehend the ecological characteristics and spatial distribution of vegetation types. This paper consequently proposes to characterize and map the different habitats of western Mount Hermon in Lebanon based on their plant communities.

Study area

Mount Hermon, or Jabal al-Shaykh in Arabic, is administratively divided into four parts: the Lebanese western slopes, the Syrian eastern slopes, the United Nations buffer zone where the United Nations Disengagement Observer Force (UNDOF) operates, and the Israeli-occupied southern slopes that are part of the Golan Heights (Dar 1988). It stands as the second-highest mountain in the Levant, reaching an elevation of 2,814 m a.s.l., and is often considered as the southern continuation of the Anti-Lebanon mountain range. The massif extends 25 km from west to east and 45 km from north to south . The entire range spans an area of approximately 1,000 km^2, with half of it located in Lebanon (Clermont-Ganneau 1903; Abel 1933).

Most of the upper stratum of Mount Hermon is dominated by Jurassic limestone (Dubertret 1955). In the mountain's circumference, Cretaceous strata occur with occasional veins of basalt (Dubertret 1955). In most of Lebanon, the soils are young, characterized by poor consistency and shallowness, especially on sloping terrains (Clermont-Ganneau 1903; Vaumas 1954). These conditions contribute to the development of terra rossa soils (Gèze 1956). On the highest slopes, rough terrain features have been created by karstic erosion, such as crags, boulders or sinkholes. Precipitation is quickly absorbed through the porous rocky substrate and feed different watersheds. Westward and southward, the waters feed the headstreams of the Jordan River, while eastward it feeds other springs descending to the Damascus basin (Abel 1933).

Mount Hermon has a typically Mediterranean climate, with January as the coldest month, and July and August as the warmest (Abi-Saleh and Safi 1988). The annual average temperature in Rashaya, at the base of Mount Hermon at 1,200 m a.s.l., is 15.6°C (Baldy 1959). In Rachaya, the mean maximum temperature of the warmest month is 34.1°C, while the mean minimum temperature of the coldest month is 0.5°C (Baldy 1959). The mean annual rainfall in Rashaya is 675 mm (Baldy 1959), reaching around 1,500 mm at peak (YMCA Lebanon 2005; Ayalon et al. 2013). Approximately 80% of the annual rainfall takes place between November and March. The growing season spans from May to mid-September, during which the majority of plant species flower and set seed.

The western slopes of Mount Hermon, part of the Lebanese territory (Figure 1), have been recognized for their floristic diversity (Arnold et al. 2015; Baydoun and Arnold 2017) and the presence of at least 21 endangered endemic plant taxa (El Zein and Kahale 2022). The flora of the area remains relatively understudied. For instance, a species not previously reported in the flora of Lebanon was recently observed there (El Zein et al. 2023). The first checklist of the flora of western Mount Hermon (Arnold et al. 2015) highlighted the significant contribution of the region to traditional ethnobotanical knowledge held by the local communities. The prolonged historical interactions between the land and the successive communities living there have given rise to diverse traditions and cultural heritages (Dar 1993; Farra Haddad 2021). Moreover, the area constitutes a repository for wild crop relatives and a cradle for the domestication of wheat ancestors (Ghossain et al. 2023).

Methods

Vegetation sampling

This study was conducted annually from 2020 to 2023, between May and August, corresponding to the spring and summer seasons, on the Lebanese western slopes of Mount Hermon, in the district of Rachaya. The sampled area ranged between elevations of 1,000 and 2,500 meters. Geographic coordinates (WGS84) for each plot were directly recorded in the field. The coordinates and elevation of the plots are provided in Suppl. material 1. We surveyed 169 circular plots, each spanning an area of 314 m^2. Several studies recommend surveying plots of large size, reaching up to 400 m^2, across diverse habitat types, including deserts, shrublands, temperate and tropical forests (Gillison 2001; Archaux et al. 2007; Hunter and Hunter 2020; Hao et al. 2021; Montenegro-Hoyos et al. 2022, Zeballos et al. 2023). For security reasons, we had to maintain a specific distance from the country borders, limiting the accessible area of the study site. The distribution of the survey plots is mapped in Figure 2. In each plot, we documented all vascular plant species, noting their respective cover-abundance through the phytosociological method (Braun-Blanquet 1932), and subsequently transformed the data using the ordinal scale (van der Maarel 1979) as follows: r: 1; +: 2; 1: 3; 2m: 4; 2a: 5; 2b: 6; 3: 7; 4: 8; 5: 9.

Artificial habitats, such as urban areas, planted forests, and agricultural lands, were not surveyed. The flora of Syria and Lebanon (Mouterde 1966, 1970, 1984) served as the reference for species identification. Species nomenclature was based on the International Plant Names Index (IPNI 2023).

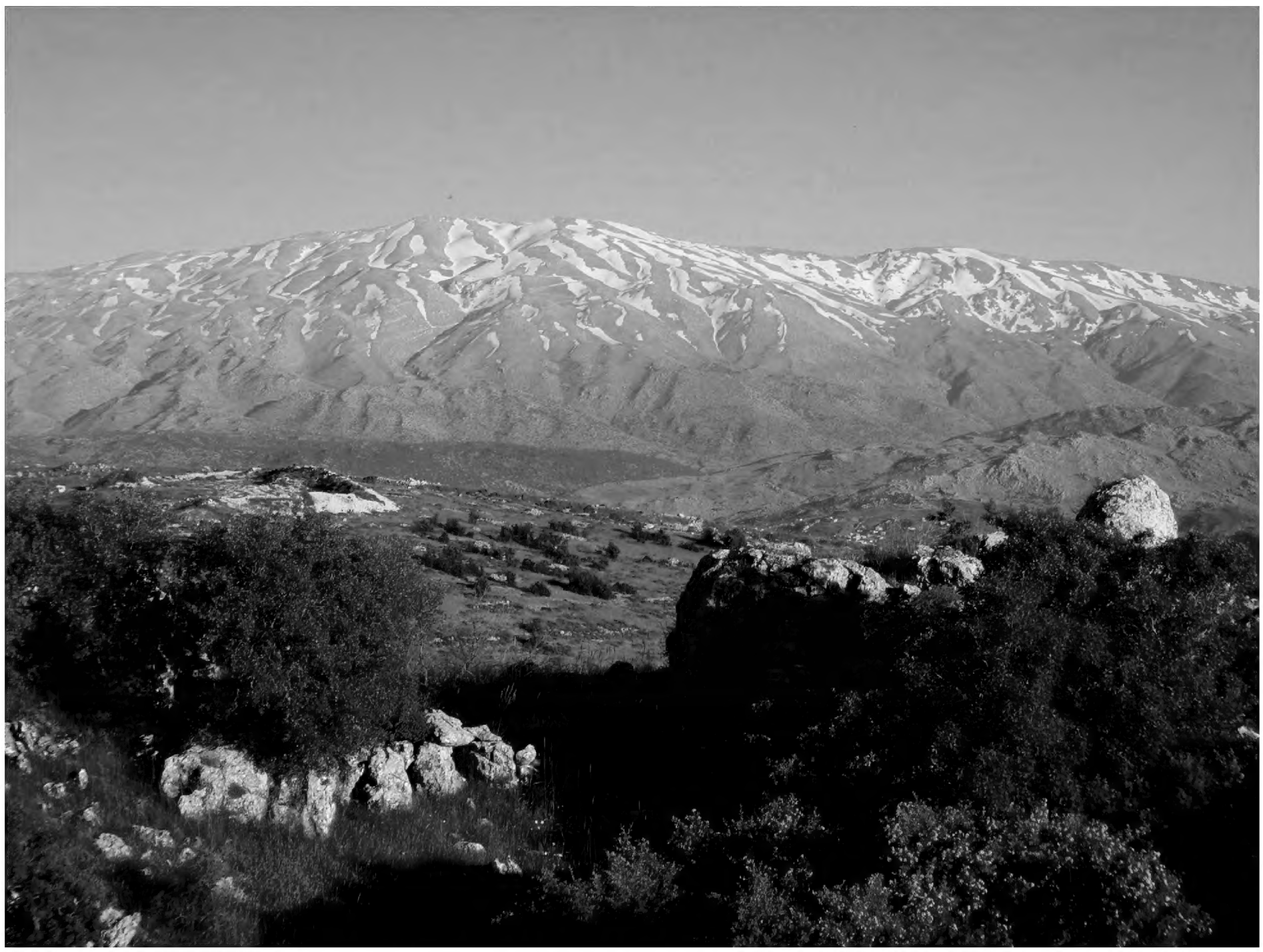

Figure 1. View on the western slopes of Mount Hermon in May 2019, Lebanon.

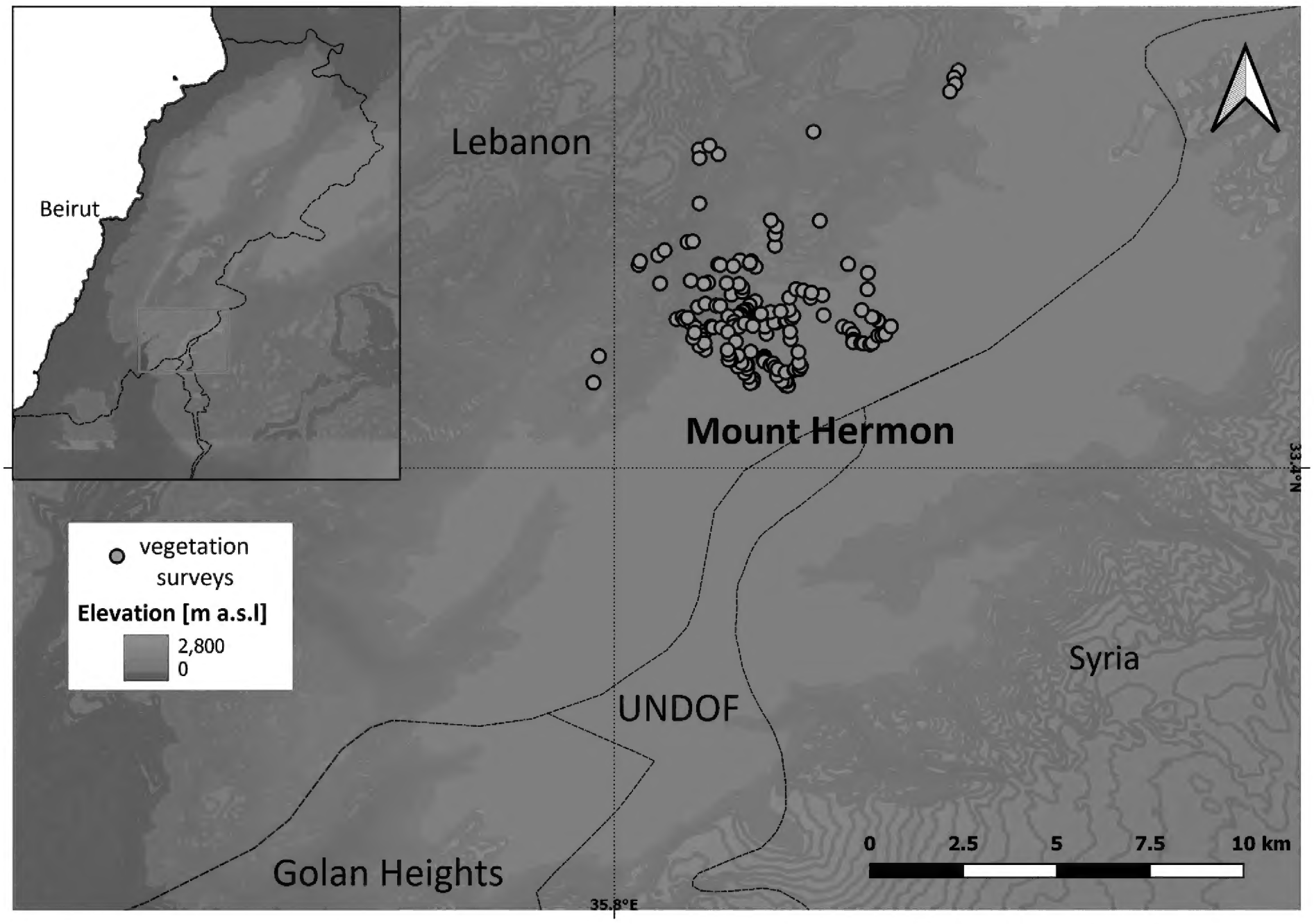

Figure 2. Map showing the geographic situation of Mount Hermon in Lebanon and vegetation plots surveyed between 2020 and 2023.

Environmental data

We extracted climatic variables, specifically the average annual precipitation and mean annual temperature calculated for the period from 1981 to 2010, from rasters provided by CHELSA database (Karger et al. 2017). The rasters have a resolution of 30 arc-seconds. Some studies demonstrated the significant role of these variables in influencing vegetation patterns and floristic composition (Dirnböck et al. 2002; Morris et al. 2016; Cabido et al. 2018; Zeballos et al. 2023). We extracted geomorphometric data, namely slope and aspect from SRTM data (Farr et al. 2007) available from the United States Geological Survey (USGS 2024), with a resolution of 1 arc-second. We transformed aspect into two components: eastness, represented by the sine, and northness, represented by the cosine. Eastness informs us about the slope orientation, ranging from west (sine = -1) to east (sine = 1). The sine value is 0 for slopes facing north or south. On the other hand, northness indicates the slope's orientation to the north (cosine = 1) or south (cosine = -1), with a cosine value of 0 for slopes facing east or west (Joly and Gillet 2017; Cheng et al. 2023). Elevation was recorded in the field. We prepared maps with the QGIS software (QGIS Development Team 2023), and downloaded the shapefiles from the DIVA-GIS website (DIVA-GIS 2023).

Data analysis

Initially, we calculated the compositional dissimilarity coefficients between sampled sites using the Bray–Curtis index, also known as the Steinhaus index (Bloom 1981; Somerfield 2008). Then, we conducted a hierarchical clustering analysis to group the sites, employing the unweighted pair group method with arithmetic mean (UPGMA; Sokal and Michener 1958; Belbin and McDonald 1993). Secondly, we applied the Nonmetric Multidimensional Scaling (NMDS) method (Kruskal 1964; Legendre and Legendre 2012) for multivariate ordination to complement the hierarchical cluster analyses. Additionally, NMDS was employed to investigate the relationship between species cover abundance per plot and environmental parameters, namely elevation, eastness, northness, slope, mean annual mean temperature and annual precipitation. The species scores were expanded based on the Wisconsin double standardization of the input data. We performed the NMDS ordination in two dimensions (Legendre and Legendre 2012). The analysis was repeated 100 times using random starting configurations to allow the algorithm to explore a larger portion of the solution space, reducing the likelihood of converging to a local minimum. For visual representation, we plotted the NMDS ordination against the environmental gradients to illustrate the ecological characteristics of the different vegetation types. We tested

the overall significance of the NMDS ordination by applying a one-way Analysis of Similarities (ANOSIM; Clarke 1993; Clarke and Warwick 1994).

In a third step, we identified diagnostic species significantly associated to the different clusters. This analysis calculates the probability of having discriminating species for each group of sampled sites. We arbitrarily set the number of clusters to 10, based on the number of groups obtained from the cluster analysis. For each taxa, we calculated the percentage frequency, which indicates the constancy, and the phi-coefficient of association, which represents the fidelity (Tichý and Chytrý 2006). The phi-coefficient ranges from -1, indicating maximum negative fidelity, to 1, indicating maximum positive fidelity. We assessed the statistical significance by direct calculation of the probability of observed taxa concentrations using Fisher's exact test. Taxa with constancy ≥ 25% and significance $p \leq 0.001$ in at least one group of sites were considered constant. Taxa with a phi > 0.6 were considered highly diagnostic, those with phi > 0.4 were deemed quite diagnostic, and those with phi > 0.23 were considered relatively diagnostic.

We carried out all statistical analyses, as well as the extraction of bioclimatic variables, using the R software (R Core Team 2022) and associated packages: *BiodiversityR* (Kindt 2023), *devtools* (Wickham et al. 2022b), *dplyr* (Wickham et al. 2023b), *geoveg* (von Lampe and Schellenberg 2023), *ggfortify* (Horikoshi et al. 2023), *ggplot2* (Wickham et al. 2023c), *ggvegan* (Simpson 2023), *labdsv* (Roberts 2023), *lattice* (Sarkar et al. 2023), *memoise* (Wickham et al. 2021), metR (Campitelli 2023), *permute* (Simpson et al. 2022), *remotes* (Csárdi et al. 2021), *rlang* (Henry and Wickham 2023), *scales* (Wickham et al. 2022a), *terra* (Hijmans et al. 2023), *tibble* (Müller et al. 2023), *tidyr* (Wickham et al. 2023a), *vegan* (Oksanen et al. 2022), and *withr* (Hester et al. 2022).

We finally associated characterised habitat types to the national habitat typology of Lebanon (El Zein et al. 2022).

Results

Species richness and endemism

The fieldwork yielded a total of 3,120 observations, documenting 383 different plant taxa within the elevation range of 1,000 and 2,500 m a.s.l. The list of the species observed is provided in Suppl. material 2. The survey comprised 47 plant families, with *Fabaceae*, *Asteraceae*, *Poaceae*, *Apiaceae*, and *Lamiaceae* accounting for 56.7% of the total identified taxa (Figure 3). *Fabaceae* consisted of 67 taxa (17.5%), *Asteraceae* of 52 taxa (13.5%), *Poaceae* of 40 taxa (10.4%), *Apiaceae* of 30 taxa (7.8%), and *Lamiaceae* of 28 taxa (7.3%). The most diverse genera were *Trifolium* with 21 taxa, followed by *Astragalus* (10), *Silene* (7), *Allium* (6), *Bromus* (6), *Crepis* (6), *Galium* (6), and *Vicia* (6). In terms of life form, the taxa were distributed between 38 phanerophytes, 22 chamaephytes, 181 hemicryptophytes, 17 geophytes, and 125 therophytes. Among the phanerophytes, we found 11 tree taxa, comprising one conifer (*Juniperus excelsa*), one broadleaf evergreen tree (*Quercus coccifera*), and nine broadleaf deciduous trees (*Acer monspessulanum* subsp. *microphyllum*, *Crataegus azarolus*, *Pistacia terebinthus*, *Prunus korshinskyi*, *P. cocomilia*, *Pyrus syriaca*, *Quercus infectoria*, *Q. look* and *Styrax officinalis*). Twenty-four taxa were endemic to Mount Hermon and Mount Lebanon, including *Allium feinbergii*, *A. libani*, *Astragalus coluteoides*, *A. cruentiflorus*, *A. hermoneus*, *Bellevalia hermonis*, *Centaurea drabifolia* subsp. *libanotica*, *C. hololeuca*, *Cousinia hermonis*, *Crepis robertioides*, *Draba antilibanotica*, *D. vesicaria*, *Galium libanoticum*, *Hypericum libanoticum*, *Lophiolepis lappacea* subsp. *hermonis*, *Marrubium globosum* subsp. *libanoticum*, *Papaver libanoticum*, *Phlomis brevilabris*, *Quercus look*, *Salvia rubifolia*, *Scilla libanotica*, *Scutellaria utriculata*, *Silene libanotica*, and *S. makmeliana*; two taxa endemic to Mount Hermon and Anti-Lebanon, namely *Centaurea iberica* subsp. *hermonis* and *Euphorbia erinacea*; and one taxon endemic exclusively to Mount Hermon, *Erysimum verrucosum*.

Classification results

The classification is illustrated in Figure 4, revealing three main branches. The first branch, highlighted in red on the left, encompasses all sites surveyed above 2,000 m a.s.l. in elevation at the oro-Mediterranean belt. The second branch, colored in green, unites sites surveyed between 1,000 and 1,600 m a.s.l. in elevation at the supra-Mediterranean level. The last branch, boxed in yellow, includes sites sampled between 1,600 and 2,000 m a.s.l. in elevation at the montane-Mediterranean level. In total, ten clusters were formed from the 169 plots. Within the oro-Mediterranean branch, we identified two clusters of thorny hedgehog-heaths and one cluster of plots surveyed in cliffs. Within the supra-Mediterranean branch, one cluster comprises plots surveyed in grasslands, along with two additional clusters of plots surveyed in woodlands, one at the meso-Mediterranean level and another at the supra-Mediterranean level. Within the montane-Mediterranean branch, we observed one cluster representing plots surveyed in shrublands, and three clusters of plots surveyed in woodlands. These included scree deciduous woodlands, partially evergreen and deciduous woodlands and deciduous woodlands.

An abbreviated synoptic table, containing only diagnostic and constant species, is provided with each cluster (Table 1). It also includes the number of plots per cluster. The entire synoptic table is presented in Suppl. materials 3, 4.

Ordination and environmental gradients

The arrangement of the sites in a two-dimensional NMDS ordination space (Figure 5) closely resemble the grouping obtained from the classification (K = 2; stress = 0.1541).

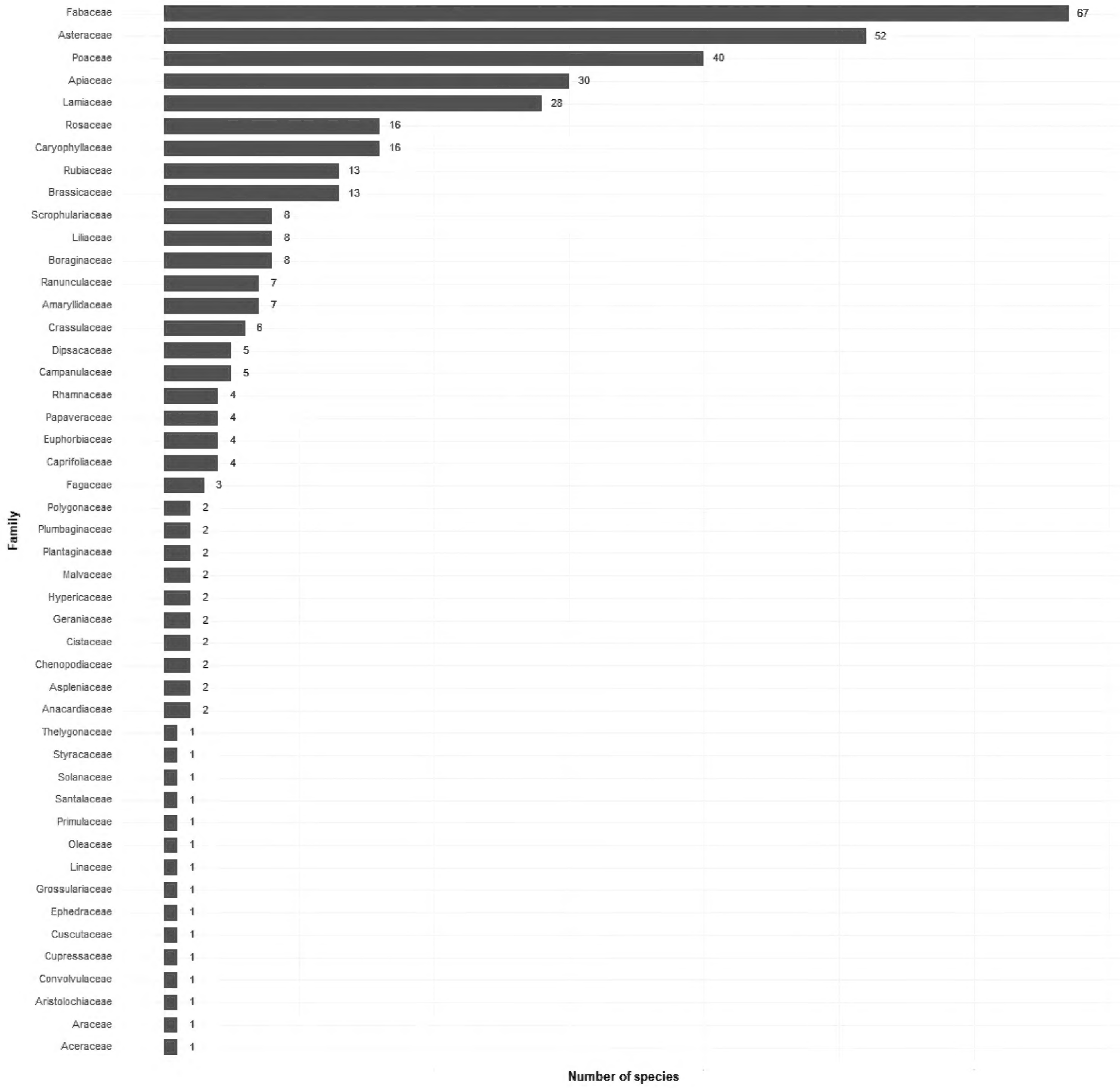

Figure 3. Number of taxa per family surveyed in Mount Hermon**.**

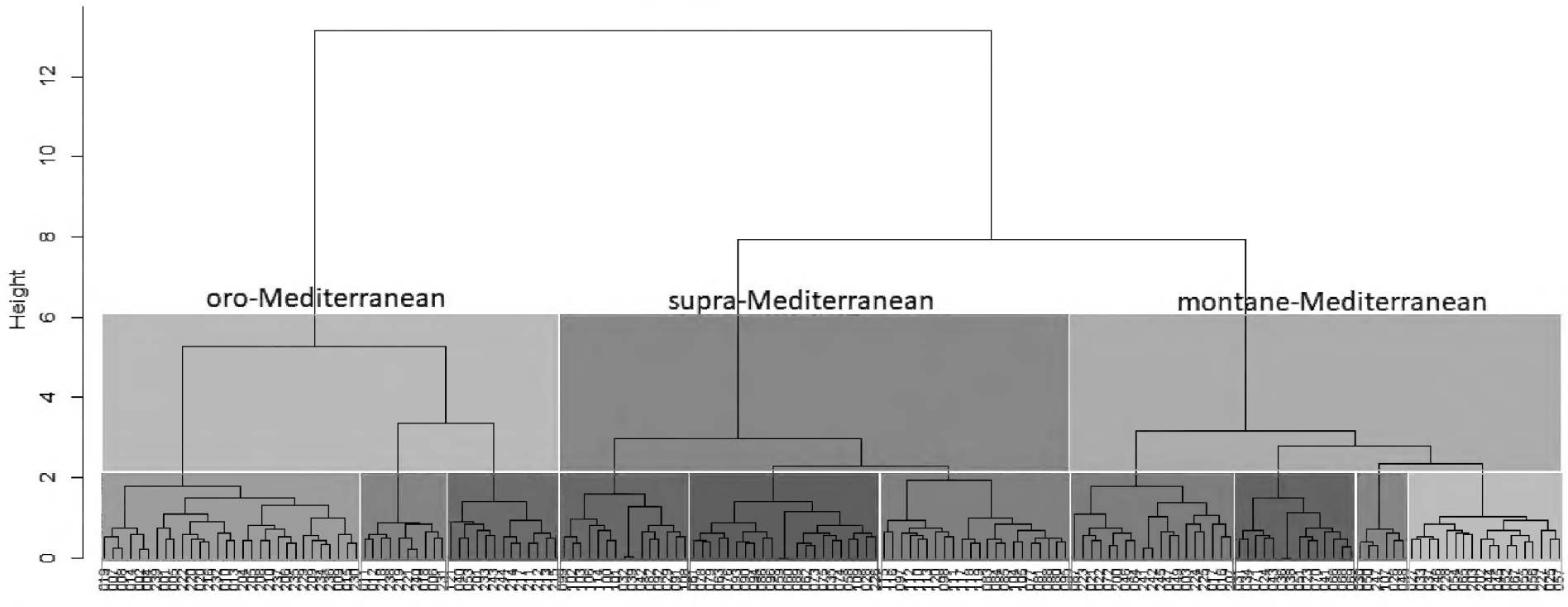

Figure 4. Cluster dendrogram built using UPGMA from the dissimilarity matrix among plots of western slopes of Mount Hermon in Lebanon.

Table 1. Abbreviated synoptic table of the ten groups obtained from the classification of 169 plots surveyed in the western slopes of Mount Hermon in Lebanon. The frequency (%) of occurrence and phi coefficient of all diagnostic and constant plant species in each group is shown. The species are sorted by decreasing fidelity (phi) within each group. phi > 0.6: dark grey; phi > 0.4: grey; phi > 0.23: light grey. Only species with constancy (Freq) ≥ 25% and significance p ≤ 0.001 in at least one group were included in the table. Vegetation types are: 1, Oro-Med. hedgehog-heaths of *Astragalus echinus* and *Noaea mucronata*; 2, Oro-Med. hedgehog-heaths of *Tanacetum densum* and *Astragalus cruentiflorus*; 3, Oro-Med. montane cliffs of *Rosularia sempervivum* subsp. *libanotica*; 4, Supra-Med. grasslands with *Eryngium glomeratum*; 5, Upper supra-Med. woodlands of *Quercus infectoria*, *Q. coccifera* and *Crataegus azarolus*; 6, Lower supra-Med. woodlands of *Quercus coccifera*; 7, Scree montane woodlands of *Prunus korshinskyi* and *Lonicera nummulariifolia*; 8, Montane woodlands of *Prunus korshinskyi* and *Quercus coccifera*; 9, Montane thickets of *Astragalus gummifer*; 10, Montane woodlands of *Quercus look* and *Acer monspessulanum* subsp. *microphyllum*. Med = Mediterranean.

Group number	**1**		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**		**10**	
Number of sites per group	30		10		13		15		22		22		19		14		6		18	
Species	**Freq**	***phi***	**Freq**	***phi***	**Freq**	***phi***	**Freq**	***phi***	**Freq**	***phi***	**Freq**	***phi***	**Freq**	***phi***	**Freq**	***phi***	**Freq**	***phi***	**Freq**	***phi***
Prunus prostrata	93	0.46	80	0.36	62	0.23														
Noaea mucronata	70	0.65																		
Astragalus echinus	60	0.63																		
Onobrychis cornuta	57	0.49																		
Cousinia hermonis	53	0.37																		
Eryngium heldreichii	50	0.65																		
Astragalus coluteoides	40	0.53																		
Acantholimon libanoticum	33	0.51																		
Verbascum cedreti	33	0.41																		
Veronica polifolia	30	0.39																		
Marrubium globosum subsp. *libanoticum*	43	0.34																		
Tanacetum densum			90	0.62	54	0.31														
Bromus tomentellus	57	0.30	90	0.58																
Alkanna orientalis			80	0.75																
Acantholimon ulicinum			70	0.71																
Astragalus cruentiflorus			60	0.63																
Sabulina juniperina			50	0.49	31	0.26														
Odontarrhena condensata subsp. *flexibilis*			30	0.53																
Rosularia sempervivum subsp. *libanotica*					92	0.70														
Ferulago trachycarpa					85	0.67														
Arabis caucasica					77	0.79														
Silene odontopetala					62	0.70														
Scrophularia libanotica var. *australis*					46	0.61														
Nepeta cilicica					46	0.41														
Rhamnus libanotica					38	0.52														
Lamium garganicum subsp. *striatum*					38	0.44														
Arenaria deflexa					31	0.53														
Campanula cymbalaria					31	0.53														
Heracleum humile					31	0.53														
Brunnera orientalis					31	0.50														
Avena sterilis			87	0.52			82	0.48												
Eryngium glomeratum			73	0.40									71	0.38						
Echinops spinosissimus subsp. *macrolepis*			67	0.48																
Trifolium boissieri			60	0.38	55	0.33	50	0.29												
Picnomon acarna			47	0.46																
Rhamnus punctata			33	0.37																
Bituminaria bituminosa			27	0.50																
Carthamus glaucus			27	0.45																
Ononis spinosa subsp. *leiosperma*			27	0.41																
Crataegus azarolus					100	0.59	59	0.27												
Salvia rubifolia					68	0.34														
Trifolium clusii					50	0.38	45	0.34												
Chrysojasminum fruticans					27	0.33														
Quercus coccifera					86	0.38	95	0.44					79	0.32						
Hordeum bulbosum			93	0.28	91	0.27											100	0.33		
Erysimum verrucosum					77	0.27											83	0.31		

Group number	1		2		3		4		5		6		7		8		9		10	
Number of sites per group	30		10		13		15		22		22		19		14		6		18	
Species	Freq	*phi*	Freq	*phi*	Freq	*phi*	Freq	*phi*	Freq	*phi*	Freq	*phi*	Freq	*phi*	Freq	*phi*	Freq	*phi*	Freq	*phi*
Dactylis glomerata									82	0.25	95	0.34							89	0.29
Trifolium stellatum											77	0.65								
Quercus infectoria									64	0.44	77	0.57								
Euphorbia hierosolymitana var. hierosolymitana											68	0.64								
Galium libanoticum											64	0.32								
Lathyrus aphaca											59	0.63								
Trifolium purpureum											59	0.57								
Trifolium grandiflorum											55	0.61								
Bromus sterilis											55	0.37								
Crepis reuteriana											50	0.58								
Lagoecia cuminoides											50	0.45								
Eryngium creticum											50	0.41								
Rhagadiolus edulis									36	0.24	50	0.38								
Poa bulbosa											50	0.38								
Campanula rapunculus subsp. *lambertiana*											41	0.52								
Lolium perenne											41	0.47								
Achnatherum bromoides											41	0.41								
Coronilla scorpioides											36	0.58								
Poa pratensis											36	0.50								
Klasea cerinthifolia											36	0.46								
Pistacia terebinthus											36	0.43								
Lapsana communis subsp. *pisidica*											36	0.42								
Scutellaria brevibracteata											36	0.34							33	0.30
Trifolium scabrum											36	0.31								
Hordeum spontaneum											32	0.54								
Ononis natrix											32	0.54								
Trifolium dasyurum											32	0.50								
Vicia tenuifolia											32	0.46								
Scabiosa palaestina											32	0.45								
Fibigia clypeata subsp. *clypeata*											32	0.40								
Trifolium plebeium											32	0.36								
Melica inaequiglumis											27	0.45								
Johrenia dichotoma											27	0.43								
Salvia multicaulis											27	0.41								
Scorzonera phaeopappa											27	0.39								
Orlaya platycarpos											27	0.39								
Allium stamineum											27	0.35								
Trifolium pilulare											27	0.33								
Galium incanum													42	0.41						
Phlomis chrysophylla									59	0.30	64	0.34			86	0.51				
Lonicera nummulariifolia													53	0.29			67	0.41		
Prunus korshinskyi													47	0.28	57	0.37				
Pseudoroegneria libanotica													47	0.28						
Euphorbia erinacea															36	0.39				
Phleum montanum															29	0.42				
Astragalus gummifer																	100	0.85		
Rubia tenuifolia									82	0.25									100	0.37
Cephalaria stellipilis													84	0.38	71	0.29			89	0.41
Quercus look															43	0.24			83	0.61
Acer monspessulanum subsp. *microphyllum*																			67	0.33
Eryngium billardierei																	33	0.26	44	0.38

Retaining the numbering and colors of the groups from the classification aids in an easy comparison with Figure 4. The degree of separation between groups, indicating differences in vegetation composition, was significant (ANOSIM R = 0.80; $p < 0.0001$). Community composition patterns per plot correlate with environmental gradients. The arrows in the ordination space represent the principal direction of variation and the strength of correlation for the environmental variables. Four environmental variables exhibited significant correlations with the NMDS axes, signifying their crucial influences in shaping vegetation composition: elevation ($r^2 = 0.889$; $p < 0.001$), mean annual temperature (temp; $r^2 = 0.858$; $p < 0.001$), slope ($r^2 = 0.227$; $p < 0.001$) and northness ($r^2 = 0.082$; $p < 0.01$). The two other environmental variables didn't show a significant correlation ($p > 0.3$): annual precipitation (precip; $r^2 = 0.012$) and eastness ($r^2 = 0.007$). Axis 1 distinctly delineates the supra-, montane- and oro-Mediterranean levels. Elevation and

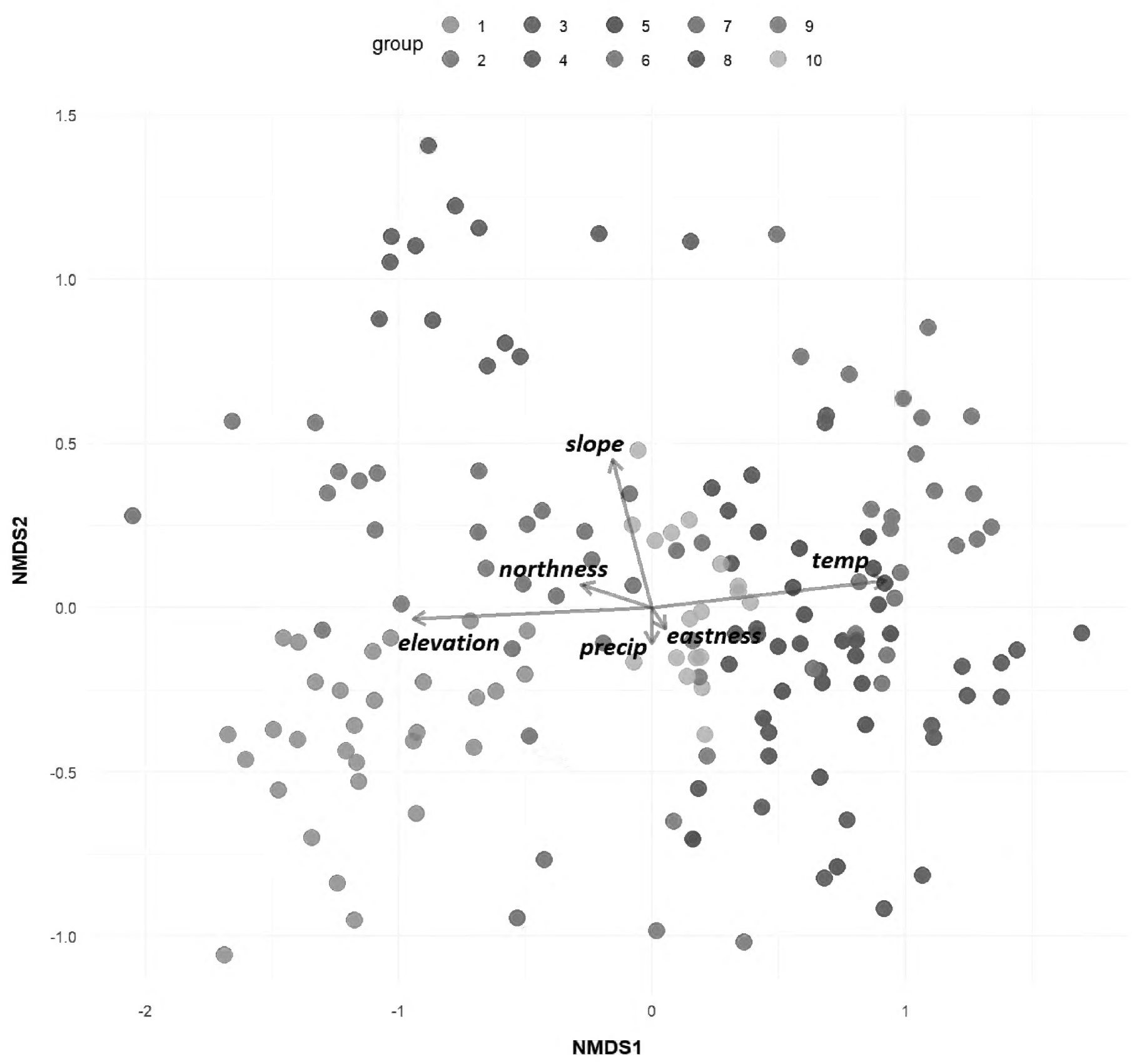

Figure 5. NMDS Ordination of 169 plots sampled in western Mount Hermon in Lebanon. Colors indicate the 10 groups obtained from the UPGMA clustering. Arrows indicate the environmental variables. temp = mean annual temperature; precip = annual precipitation.

temperature run almost parallel to the first axis, indicating a direct relationship between these two environmental variables. Therefore, Axis 1 can be interpreted as an altitudinal gradient where temperature increases in the opposite direction. Axis 2 separates clusters within each altitudinal level, with slope being the variable most correlated to this axis. The fourth significant variable, northness, displays a diagonal orientation in the ordination space, suggesting a combined correlation with variations along both NMDS axes.

Characterisation of habitat types

The habitat types are described based on the grouping obtained from the classification, the correlation with environmental variables, as displayed in the NMDS ordination, and their constant and diagnostic plant species. The code of habitat type according to the Lebanese national typology is also provided. The habitats are presented in the same order of grouping of the classification.

Oro-Mediterranean belt (2,000–2,800 m a.s.l.)

In Mount Hermon, the oro-Mediterranean belt features a complex succession of low thorny-cushion shrublands, rocky grasslands, limestone rock pavements, cliffs and screes. The environment of this altitudinal belt is characterised by bare mineral substrate with limited soil presence and scarce vegetation cover owing to harsh climatic conditions, including abundant precipitation, snow cover in winter, prolonged summer drought, and the intense wind.

1. Oro-Mediterranean hedgehog-heaths of *Astragalus echinus* and *Noaea mucronata* in thalweg and slopes – S759_LB1

This habitat is composed of low thorny-cushion shrublands known as hedgehog-heaths (Figure 6). This vegetation is characterised by the diagnostic species *Prunus prostrata*, *Noaea mucronata*, *Astragalus echinus*, *Onobrychis cornuta*, *Cousinia hermonis*, *Eryngium heldreichii*, *Astragalus coluteoides*, *Acantholimon libanoticum*, *Verbascum cedreti*, and *Veronica polifolia* in decreasing diagnostic

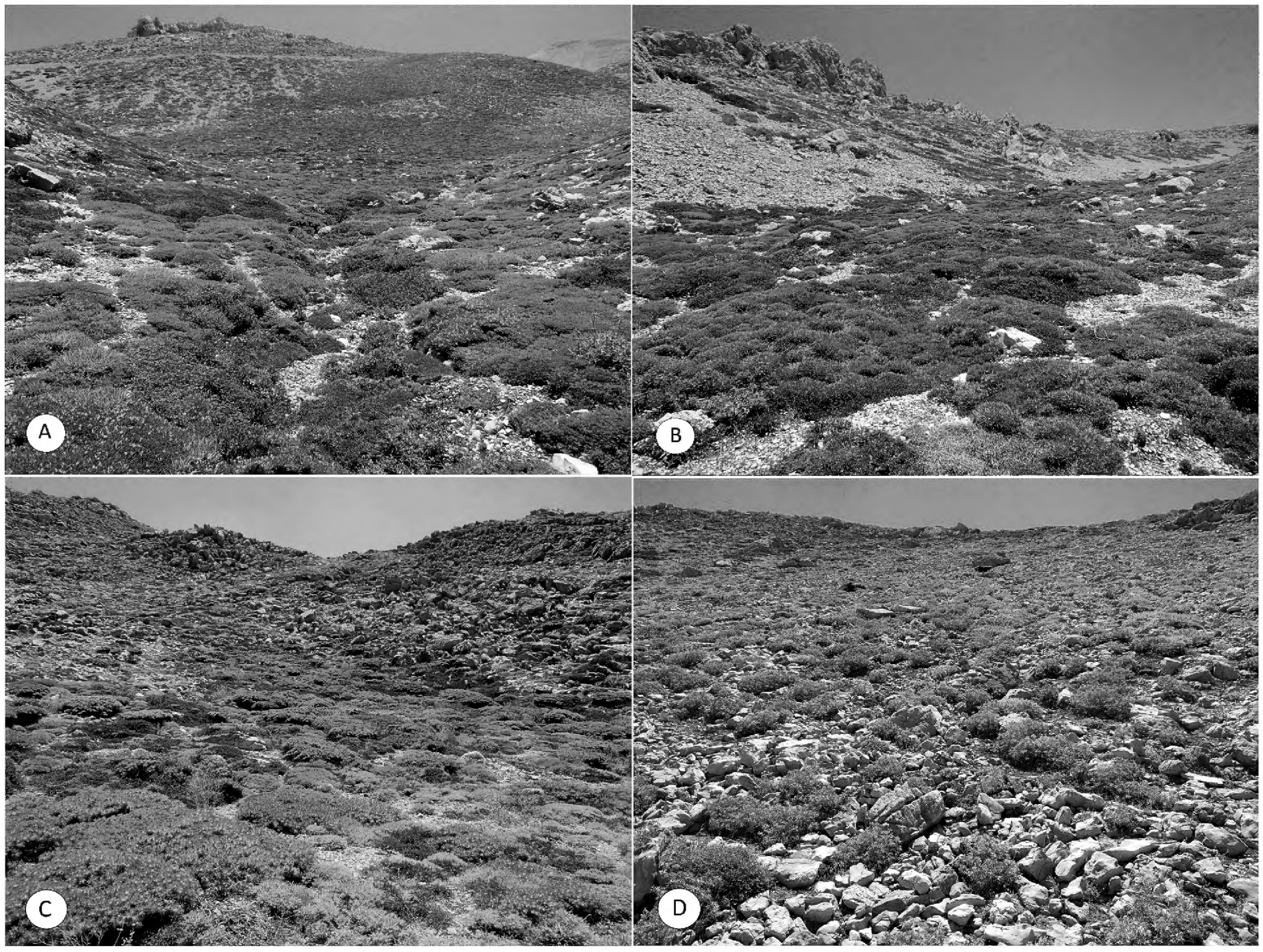

Figure 6. Oro-Mediterranean hedgehog-heaths of *Astragalus echinus* and *Noaea mucronata* in thalweg and slopes in the western slopes of Mount Hermon in Lebanon in 2020 **A.** Dominated by *Astragalus hermoneus* and *A. coluteoides*; **B.** Dominated by *Onobrychis cornuta* and *Prunus prostrata*; **C.** Dominated by *A. echinus* and *Noaea mucronata*; **D.** Dominated by *Eryngium heldreichii*.

value. This type of hedgehog-heaths is found in slopes and thalweg where the soil is relatively deeper. Other taxa are commonly found without being diagnostic or constant, namely *Astragalus hermoneus*, *A. nummularius* subsp. *trichopterus*, *Campanula stricta* var. *libanotica*, *Cruciata taurica*, *Dichoropetalum alpinum* and *Teucrium orientale*. Twelve of the twenty-six endemic taxa, such as *Astragalus hermoneus*, *Lophiolepis lappacea* subsp. *hermonis*, *Marrubium globosum* subsp. *libanoticum*, and *Phlomis brevilabris*, were observed in this habitat type.

2. Oro-Mediterranean hedgehog-heaths of *Tanacetum densum* and *Astragalus cruentiflorus* – S759_LB1

This habitat represents another type of hedgehog-heath, distinguished by the diagnostic taxa *Tanacetum densum*, *Bromus tomentellus*, *Alkanna orientalis*, *Acantholimon ulicinum*, *Astragalus cruentiflorus*, *Sabulina juniperina*, and *Odontarrhena condensata* subsp. *flexibilis* in decreasing diagnostic value (Figure 7). The surveyed sites exhibited pronounced xerophytic conditions, attributed to their exposure to wind and sun, along with the scarcity of soil, typical of sites located on the hilltops or south-oriented slopes. Three endemic taxa, namely *Cousinia hermonis*, *Draba antilibanotica*, and *D. vesicaria*, were observed in this habitat type.

3. Oro-Mediterranean and montane limestone cliffs of *Rosularia sempervivum* subsp. *libanotica* – U38

Limestone cliffs are present in both montane and oro-Mediterranean levels (Figure 8). The diagnostic taxa are *Rosularia sempervivum* subsp. *libanotica*, *Ferulago trachycarpa*, *Arabis caucasica*, *Silene odontopetala*, *Scrophularia libanotica* var. *australis*, *Rhamnus libanotica*, *Lamium garganicum* subsp. *striatum*, *Arenaria deflexa*, and *Campanula cymbalaria* in decreasing diagnostic value. Some diagnostic species are always located at the bottom of the cliffs, namely *Nepeta cilicica*, *Heracleum humile*, and *Brunnera orientalis*. Four endemic taxa, namely *Bellevalia hermonis*, *Centaurea drabifolia* subsp. *libanotica*, *Scutellaria utriculata*, and *Silene makmeliana*, were observed in this habitat type.

Supra-Mediterranean belt (1,000–1,600 m a.s.l.)

The supra-Mediterranean altitudinal level is characterised by the presence of sclerophyllous forests of *Quercus coccifera* and deciduous broadleaf woodland of *Q. infectoria*, primarily found in the hills at the base of Mount Hermon. This altitudinal belt exhibits a predilection for human activities. The general landscape consisted of rocky

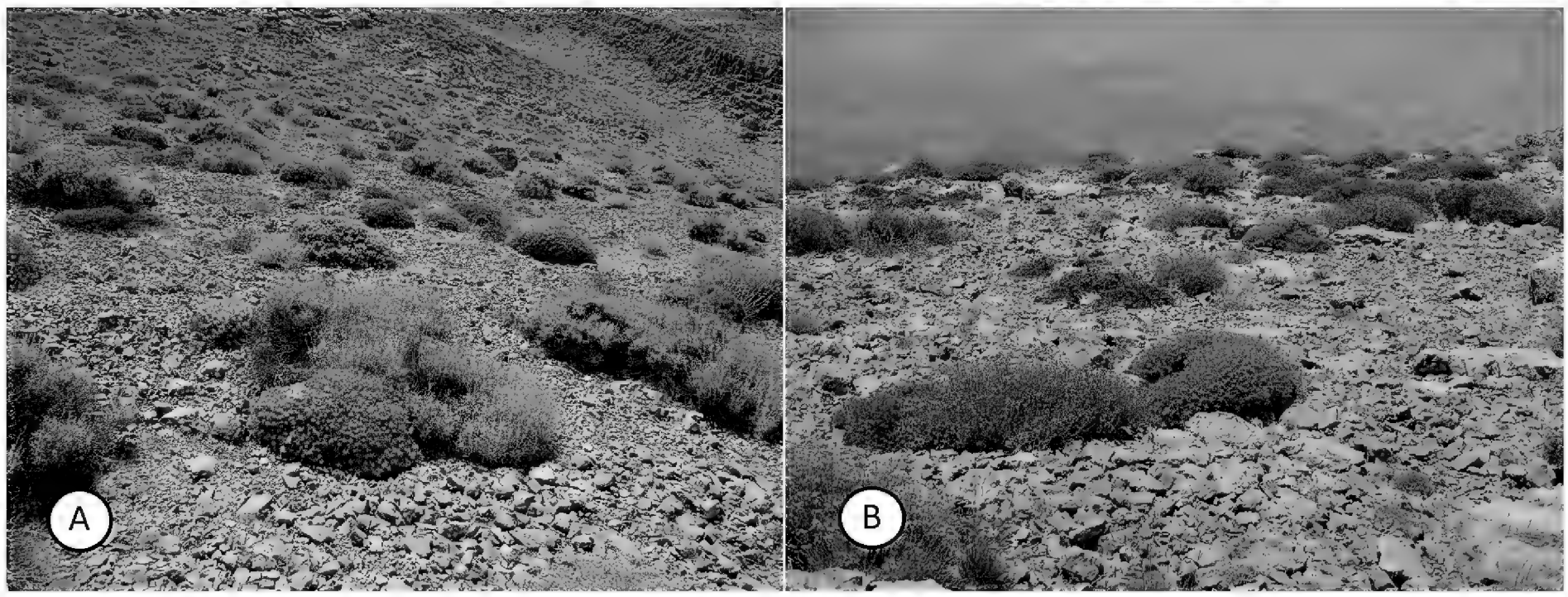

Figure 7. Oro-Mediterranean hedgehog-heaths of *Tanacetum densum* and *Astragalus cruentiflorus* in the western slopes of Mount Hermon in Lebanon in 2022.

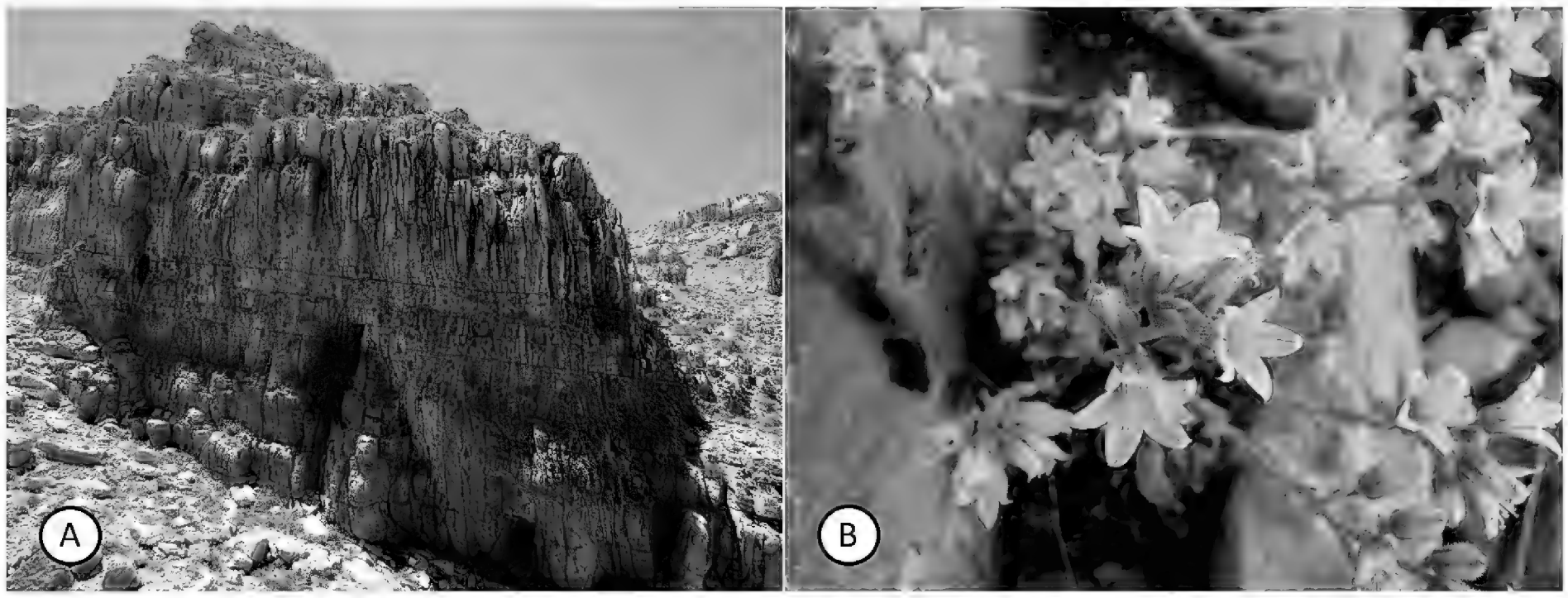

Figure 8. A. Limestone cliffs at the oro-Mediterranean level in the western slopes of Mount Hermon in Lebanon in 2022; **B.** *Rosularia sempervivum* subsp. *libanotica* in flower.

grasslands and shrublands used as pastures, interspersed with patches of woodlands, agricultural fields, and human settlements.

4. Supra-Mediterranean grasslands with *Eryngium glomeratum* – R1E_LB1

These grasslands are the results of the degradation of the supra-Mediterranean evergreen woodlands of *Quercus coccifera* and evergreen-deciduous woodlands of *Q. infectoria* (Figure 9). They are maintained as grasslands by intensive grazing which prevent the recolonisation by trees. The diagnostic taxa are *Avena sterilis*, *Eryngium glomeratum*, *Echinops spinosissimus* subsp. *macrolepis*, *Hordeum bulbosum*, *Trifolium boissieri*, *Picnomon acarna*, *Rhamnus punctata*, *Bituminaria bituminosa*, *Carthamus glaucus*, and *Ononis spinosa* subsp. *leiosperma* in decreasing diagnostic value. Sometimes very sparse shrubs or low trees of *Q. coccifera*, dwarfed by overgrazing, occur in the rocky grasslands. Two endemic taxa, *Astragalus oleifolius* and *Centaurea iberica* subsp. *hermonis*, were observed in this habitat type.

5. Upper supra-Mediterranean deciduous woodlands of *Quercus infectoria*, *Q. coccifera*, and thickets of *Crataegus azarolus* – T1953_LB1

This group includes two distinct types of vegetation that share a similar floristic composition. One of them, the thickets of *Crataegus azarolus*, represents the degraded form of the deciduous woodlands of *Q. infectoria*, and *Quercus coccifera* (Figure 10). The prevalence of *Quercus infectoria*, either dominantly or in conjunction with *Quercus coccifera*, is a defining characteristic of this woodland type, referred to as sub-Mediterranean thermophilous deciduous oak forest. The diagnostic species are *Crataegus azarolus*, *Salvia rubifolia*, *Trifolium clusii*, *Chrysojasminum fruticans*, *Q. coccifera* and *Q. infectoria*. Thickets are dense stands of shrubs or low trees, typically not exceeding 2 m in height. The thickets of *C. azarolus* are widespread at the upper supra-Mediterranean level, resulting from the degradation of woodlands. These formations act as pioneer habitats, colonising abandoned agricultural terraces and paving the way for the subsequent establishment of oak

Figure 9. Supra-Mediterranean grasslands in the western slopes of Mount Hermon in Lebanon in 2020 **A.** above Qsar el-Jabal, next to Ain Hircha in summer; **B.** above Berket el-Yebse in spring.

Figure 10. Upper supra-Mediterranean woodlands of *Quercus infectoria*, Q. *coccifera* with thickets of *Crataegus azarolus* in 2020 **A.** In Hima Hassan, in July; **B.** A thalweg with grassland within the woodland above Kfar Qouq in May; **C.** Contrast between preserved woodlands above Hima el-Kadarin on the left and degraded woodland with thickets of C. *azarolus* characterized by their reddish color in August; **D.** Degraded slope with remaining Q. *infectoria* in July.

forests. The thickets are scattered intermittently, alternating with extensive patches of grasslands, where *Phlomis chrysophylla*, *Hordeum bulbosum*, *Rubia tenuifolia*, and *Erysimum verrucosum* are also considered diagnostic species, albeit with a low fidelity coefficient as they are also found in other vegetation groups. *Erysimum verrucosum* is endemic to Mount Hermon, and *Salvia rubifolia* is endemic to Mount Lebanon, Anti-Lebanon ranges, and Mount Hermon. In total, four endemic taxa were observed in these habitat types.

The dominance of the evergreen *Q. coccifera* and deciduous *Q. infectoria* in woodlands alternates according to geomomorphology and soil depth. Small hills with rocky and shallow soils host woodlands of *Q. coccifera*. In contrast, thalwegs, characterised by the presence of soil, greater protection from the wind, and lower sun exposition, support woodlands with tall trees, particularly *Q. infectoria*. However, in the past, some parts of Mount Hermon's thalwegs were preferred for wood exploitation and agriculture, leading to tree removal. Areas with soils are distributed between the rocky hills, giving them this linear shape. Presently, some of these thalwegs face intensive grazing, hindering the regeneration of the deciduous woodlands. This has resulted in a composite landscape featuring alternating successions of linear thalwegs grasslands with tall *Q. infectoria* trees inserted among rocky hills with evergreen shorter *Q. coccifera* trees, creating a characteristic mosaic of vegetation types.

6. Lower supra-Mediterranean evergreen *Quercus coccifera* woodlands – T213_LB2

Climactic forests of the lower supra-Mediterranean in western Mount Hermon are characterised by the dominance of *Quercus coccifera*, reaching up to 70% of the proportion of trees in some sites (Figure 11). Stands are dense but often low, not exceeding 4 m in height, and display a coppice physiognomy believed to be a result of a long history of exploitation and forest fires. Some of the most significant diagnostic tree species of this habitat are *Q. coccifera*, *Q. infectoria* and *Pistacia terebinthus*. Some of the most significant diagnostic herbaceous taxa are *Dactylis glomerata*, *Trifolium stellatum*, *T. purpureum*, *T. grandiflorum*, *Euphorbia hierosolymitana* var. *hierosolymitana*, *Galium libanoticum*, *Lathyrus aphaca*, *Bromus sterilis*, *Crepis reuteriana*, *Lagoecia cuminoides*, *Eryngium creticum*, *Rhagadiolus edulis*, *Poa bulbosa*, *P. pratensis*, *Campanula rapunculus*, *Lolium perenne*, *Achnatherum bromoides* and *Klasea cerinthifolia*. Four endemic taxa, namely *Centaurea iberica* subsp. *hermonis*, *Galium libanoticum*, *Salvia rubifolia*, and *Silene makmeliana*, were observed in these habitat types.

Montane-Mediterranean belt (1,600–2,000 m a.s.l.)

Mount Hermon is distinctive for hosting sparse deciduous woodlands, primarily composed of the endemic thermophilous oak *Quercus look*. The specific topography, slope aspect, and steepness play crucial roles in determining the type of woodlands present. Additionally, historical tree exploitation has significantly impacted the physiognomy of these woodlands, often resulting in a succession of sparse woodlands and degraded habitats, such as rocky shrublands, rocky grasslands, and screes.

7. Scree deciduous montane woodlands of *Prunus korshinskyi* and *Lonicera nummulariifolia* – T19B9_LB1

Steep slopes of unstable limestone screes in the montane-Mediterranean belt are predominantly covered with sparse woodlands, primarily dominated by *Prunus korshinskyi* or *Lonicera nummulariifolia* (Figure 12). These formations, rarely exceeding 3 m in height, feature *P. korshinskyi* and *L. nummulariifolia* along with diagnostic herbaceous species well-adapted to screes and unstable rocky substrate, such as *Galium incanum*, *Cephalaria stellipilis* and *Pseudoroegneria libanotica*. Other taxa commonly found on rocky outcrops and scress were frequently observed, though not considered diagnostic, including the sub-shrub *Atraphaxis billardierei* and other forbs, such as *Allium libani*, *Arrhenatherum kotschyi*, *Cousinia hermonis*, *Hypericum libanoticum*, *Nepeta glomerata* and *Scrophularia peyronii*. Six endemic taxa, namely *Allium libani*, *Cousinia hermonis*, *Erysimum verrucosum*, *Euphorbia erinacea*, *Hypericum libanoticum* and *Scutellaria utriculata* were observed in these habitat types.

8. Montane woodlands of deciduous *Prunus korshinskyi* and evergreen *Quercus coccifera* – T19B9_LB1 X T213_LB2

These montane woodlands typically develop on stable rocky slopes, often at hilltops or on west-oriented slopes (Figure 13). They form sparse woodlands alternating with low garrigues of *Phlomis*. The diagnostic species include deciduous *Prunus korshinskyi*, *Phlomis chrysophylla*,

Figure 11. *Quercus coccifera* woodlands. **A.** In Wadi el-Feqaa; **B.** In Hima el-Kadarin.

Figure 12. Montane deciduous woodlands on screes on the western slopes of Mount Hermon in Lebanon in 2020: **A.** with *Prunus korshinskyi*; **B.** with *Lonicera nummulariifolia*; **C.** Fruit of *Prunus korshinskyi*; **D.** Flowers of *Lonicera nummulariifolia*.

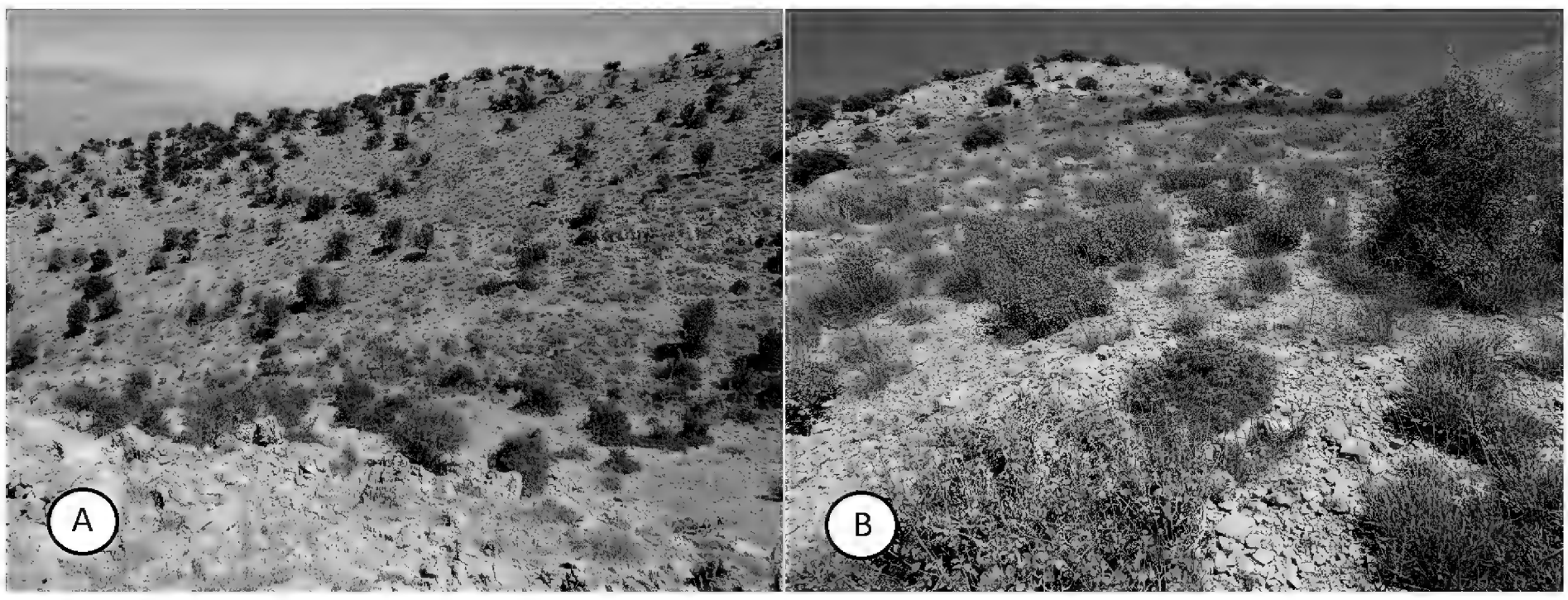

Figure 13. A. Montane woodlands of deciduous *Prunus korshinskyi* and evergreen *Quercus coccifera* on the western slopes of Mount Hermon in Lebanon in 2020; **B.** With garrigues of *Phlomis chrysophylla*.

Phleum montanum, and *Euphorbia erinacea*. While evergreen *Quercus coccifera* was a constant species, it was not considered diagnostic. In some areas with more intense grazing, the trees are reduced to low, compact and rounded shrubs, transforming the appearance of woodlands into garrigues. *Q. coccifera* is particularly susceptible to these effects. During the surveys in these woodlands, at around 1,600 m elevation, few isolated individuals of *Juniperus excelsa* were found. Apart from *Quercus look* and *Euphorbia erinacea*, two other endemic taxa were observed in this habitat type, namely *Hypericum libanoticum* and *Scutellaria utriculata*.

9. Montane-Mediterranean thalweg deciduous thickets of *Astragalus gummifer* –S3575_LB3

This type comprises montane deciduous thickets in thalwegs formed by *Astragalus gummifer*, a spiny shrub that can reach up to 1 m height and occupy up to 90% of the surface, restricting the establishment of other species (Figure 14). In areas with scree substrate, *Lonicera nummulariifolia* woodlands were observed in the contact zone around the thickets. Other taxa were commonly found without being diagnostic, such as the herbaceous *Eryngium billardierei*, *Erysimum verrucosum*, *Ferula bivertiicellata*, *Hordeum bulbosum*, *Marrubium globosum* subsp. *libanoticum*, and *Phlomis brevilabris*. Five endemic taxa were observed in this habitat type, namely *Centaurea iberica* subsp. *hermonis*, *Erysimum verrucosum*, *Galium libanoticum*, *Marrubium globosum* subsp. *libanoticum*, and *Phlomis brevilabris*.

10. Montane-Mediterranean deciduous *Quercus look* and *Acer monspessulanum* subsp. *microphyllum* woodlands – T1953_LB3

Quercus look, a thermophilous deciduous oak, forms small relictual clumps of trees or sparse woodlands in the montane-Mediterranean belt (Figure 15). The substrate is predominantly rocky, with soil poorly developed on limestone bedrock. Individuals of *Q. look* can reach up to 5 m height but are sometimes reduced to branched shrubs due to logging and overgrazing. Other diagnostic taxa were *Rubia tenuifolia*, *Cephalaria stellipilis*, *Acer monspessulanum* subsp. *microphyllum*, and *Eryngium billardierei* in decreasing diagnostic value. *A. monspessulanum* subsp. *microphyllum* is a tree often not exceeding 3 m height and, at times, reduced to low, compact, and rounded shrubs. The vine *Rubia tenuifolia* was prevalent in this habitat, observed growing without support, creeping at ground level, although it is typically widespread in Levantine woodlands at lower altitudes. Although not considered diagnostic, other taxa were relatively common in this habitat, such as the grass species *Dactylis glomerata*, *Elymus panormitanus*, and *Hordeum bulbosum*, as well as some forbs, such as *Anthemis pauciloba*, *Bupleurum exaltatum*, *Erysimum verrucosum*, *Nepeta cilicica*, *N. italica*, *Salvia rubifolia*, *Scutellaria brevibracteata*, and *Silene libanotica*. Ten endemic taxa were present in this habitat type, namely *Astragalus nummularius* subsp. *trichopterus*, *Centaurea iberica* subsp. *hermonis*, *Erysimum verrucosum*, *Euphorbia erinacea*, *Galium libanoticum*, *Hypericum libanoticum*, *Q. look*, *Salvia rubifolia*, *Scutellaria utriculata*, and *Silene libanotica*.

Habitat mapping

The mapping of habitat types of the western slopes of Mount Hermon encompassed areas characterised by their floristic composition (Figure 16), as well as agricultural fields, urbanised areas and planted forests.

Phryganas of *Sarcopoterium spinosum* (S7242) were sampled only once and grouped with supra-Mediterranean grasslands (cluster 4). However, they were mapped separately. These were confined to a small area in the foothills of Mount Hermon, typically occurring below 1,250 m of elevation. A single survey proved inadequate to fully characterise the floristic particularities of this habitat.

The last remaining population of *Juniperus excelsa* (T3D71) on the western slopes of Mount Hermon was located during fieldwork and consequently included in the mapping. Due to access restrictions, this habitat could not be physically reached and sampled.

Given the intricate and interwoven mosaics formed by related habitats sharing similar flora, the oro-Mediterranean habitats of hedgehog-heaths of *Astragalus echinus* and *Noaea mucronata* in thalweg and slopes, hedgehog-heaths of *Tanacetum densum* and *Astragalus cruentiflorus*, and cliffs of *Rosularia sempervivum* subsp. *libanotica*, were treated as a unified polygon. A similar approach was applied to the montane-Mediterranean woodlands of *Prunus korshinskyi* associated with *Lonicera nummulariifolia* or with *Quercus coccifera* in combination with *Phlomis chrysophylla* garrigues.

Figure 14. *Astragalus gummifer* thickets in thalwegs in the western slopes of Mount Hermon in Lebanon. **A.** View from a distance; **B.** Close-up.

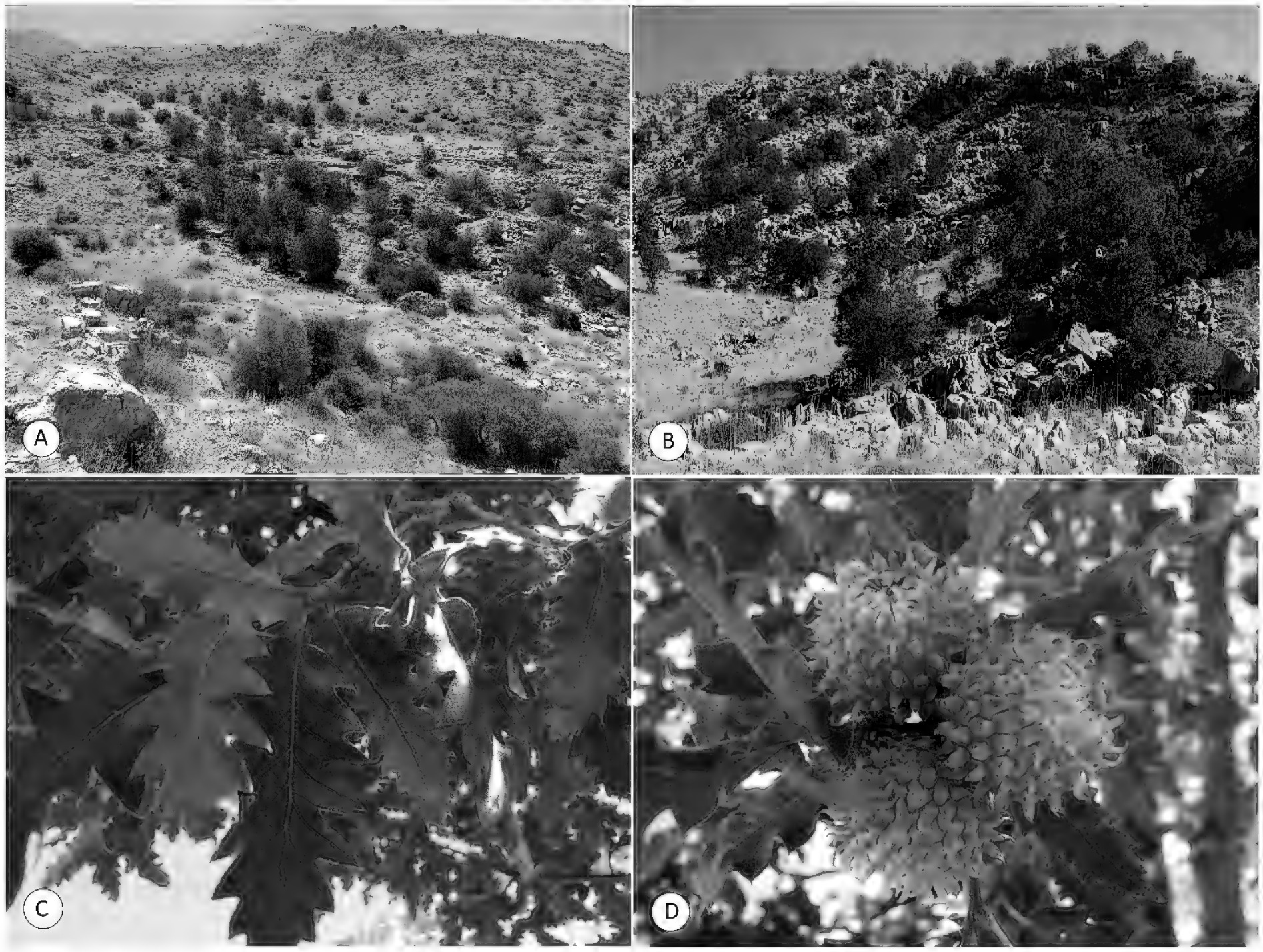

Figure 15. Montane woodlands of *Quercus look* and *Acer monspessulanum* subsp. *microphyllum* in the western slopes of Mount Hermon in Lebanon in 2020: **A. B.** Patches of woodlands; **C.** Leaves of Q. *look*; **D.** Immature acorns.

Figure 16. A. Contrast between the slope of phrygana on the left and the slope with evergreen oak woodlands in Wadi el-Feqaa; **B.** Close-up on phrygana of *Sarcopoterium spinosum*.

Patches of cultivated lands are dispersed at lower altitudes, encircling villages or situated on plateaus up to an elevation of 1,550 meters (Figure 17). These cultivated areas are mostly concentrated in thalwegs, where the soil is deeper and more level compared to the surrounding hilly, rocky slopes. This phenomenon accounts for the linear layout of numerous agricultural lands in the region. Rain-fed fields cultivating cereals (barley, wheat) and legumes (chickpeas, lentils) are prevalent. Terraced cultivation includes grapevines and fruit trees such as almonds, cherries and walnuts.

During the study, two planted forest sites were explored, although their flora was not surveyed. Comprising a mix of three conifers non-native to Mount Hermon, namely *Cupressus sempervirens*, *Pinus brutia*, and *Cedrus libani*,

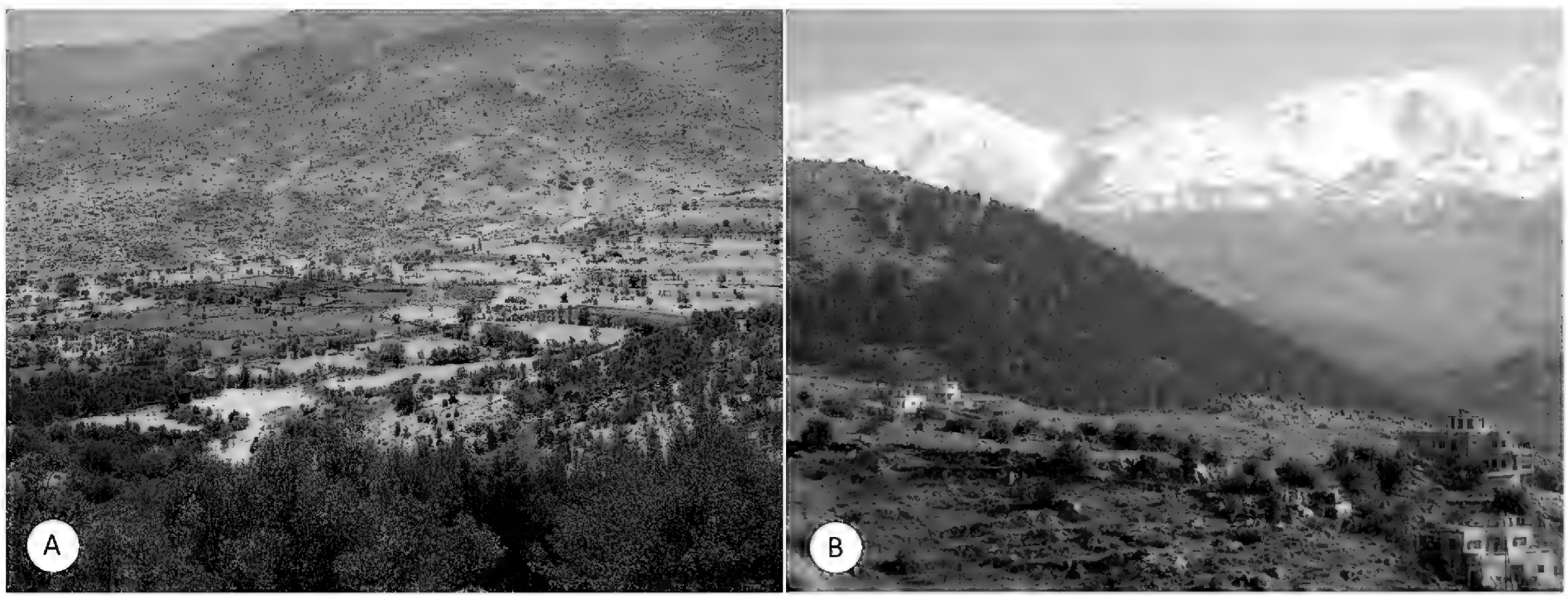

Figure 17. A. Agricultural lands in Berke el-Yebse ; **B.** Planted forest viewed from Rachaya.

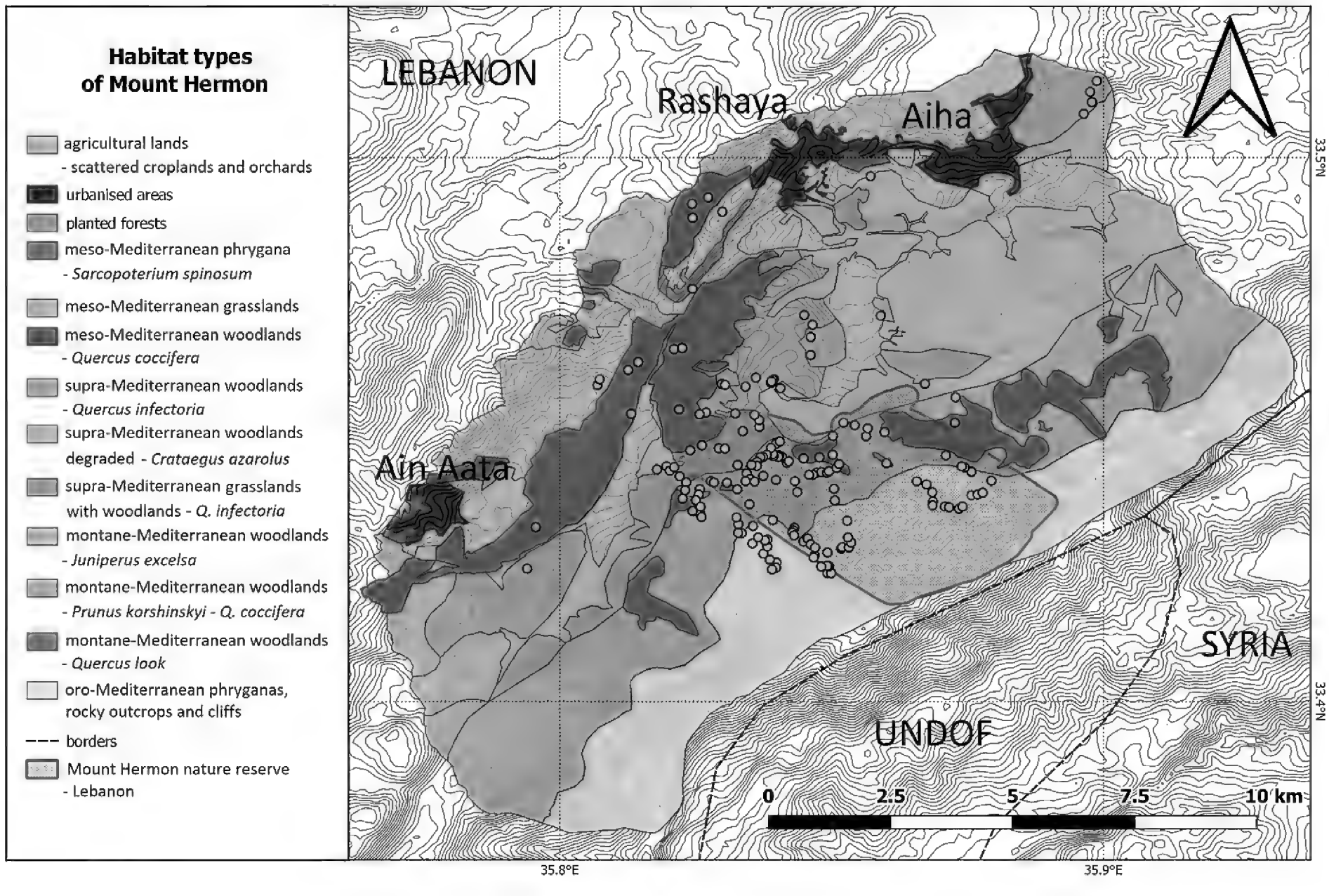

Figure 18. Map of the habitat types identified on the western slopes of Mount Hermon in Lebanon.

these forests were planted in the 1960s by the Ministry of Agriculture. The trees in these planted forests exceed 5 m height. Undoubtedly, these forests play a crucial ecological role in the area, serving as a refuge for numerous wild animals, including birds and mammals.

Finally, the surveys and the boundaries of the nature reserve were mapped to illustrate the range of the habitat types included within the 12.89 km² of protected area (Figure 18). The nature reserve of the western slopes of Mount Hermon comprehensively represents oro- and montane-Mediterranean habitats, as well as upper supra-Mediterranean woodlands and their degraded form of *Crataegus azarolus* thickets.

Discussion

The floristic study conducted on the western slopes of Mount Hermon enabled the characterisation of ten habitat types, based on species differences and the influence of four significant environmental variables. Elevation and mean annual temperature emerged as the most influential factors shaping floristic composition. Although mean annual temperature and elevation exhibit a direct relationship, it is prudent to consider them separately due to the varied influences associated with them. Slope ranked as the third most significant environment variable, notably influencing floristic variation among the habitat groups

of the oro-Mediterranean level. Northness also exerted a significant influence, particularly affecting the differentiation of the scree woodlands of *Prunus korshinskyi* from the other montane habitats.

Five habitat types represent novelties, constituting subtypes of broader habitat types described in the national typology (El Zein et al. 2022). They include the description of two types of hedgehog-heaths at the oro-Mediterreanean level. The group of *Astragalus echinus* and *Noaea mucronata* exhibits a preference for slopes and thalwegs where exposure to wind and sun is reduced, and the soils is deeper. The group of *Tanacetum densum* and *Astragalus cruentiflorus* thrives on hilltops and south-oriented slopes, showing a preference for xeric and rocky situations. Hedgehog-heaths are unique habitats and constitute relict vegetation poorly studied in the Levant, primarily composed of endemics or rare species belonging to the ancient Mediterranean Tertiary flora (Musarella et al. 2020). Both of these habitats are endemic to Mount Lebanon, Mount Hermon and Anti-Lebanon, indicated by the presence of taxa strictly endemic to these ranges. The first habitat includes *Astragalus coluteoides*, *A. hermoneus*, and *A. nummularius* subsp. *trichopterus*, while the second contains the diagnostic species *A. cruentiflorus*.

Another novelty is the description of a plant group diagnostic of the cliffs at the oro-Mediterranean level in western Mount Hermon. This group comprises twelve taxa, with *Rosularia sempervivum* subsp. *libanotica* having the highest diagnostic value, and the majority of them are endemic to the mountains of South Turkey, Mount Lebanon, Anti-Lebanon and Mount Hermon. We propose categorizing this habitat as a sub-type of "*Mediterranean bare limestone inland cliffs*" (U387) of the national habitat typology, specifically characterizing the oro-Mediterranean limestone cliffs of Mount Hermon in Lebanon. This contributes significantly to our understanding of plant communities on cliffs, as this habitat has remained poorly studied in the Levant, and oro-Mediterranean cliffs of this region were previously undocumented (Davis 1951; Wagensommer 2017).

The scree deciduous montane woodlands of *Prunus korshinskyi* and *Lonicera nummulariifolia* represent a habitat type that has been insufficiently characterised in the past. This unique habitat is distinguished by its specific substrate, notably the screes, and the distinctive aspect of the slope. The formations of *P. korshinskyi* show affinities with the Arabic Peninsula (Zohary 1973), while the presence of *L. nummulariifolia* characterises typical Eastern Mediterranean and Irano-Turanian habitats (Davis et al. 1965). At the Lebanese level, woodlands featuring *P. korshinskyi* are a rarity and are exclusively found on the eastern slopes of Mount Lebanon between Wadi Faara, Ainata and Yammoune in a limited area (Mouterde 1966, 1970). We propose this habitat as a sub-type of "*Lebanese wild fruit trees steppe wood*" of the national typology (T19B9_LB1). The second montane woodland including *P. korshinskyi* in association with *Quercus coccifera* constitutes a second sub-habitat.

Quercus look is a tree endemic to Mount Lebanon, Anti-Lebanon and Mount Hermon (Avishai 2017). The inhabitants of the region of Rachaya historically distinguished this oak species from others, assigning it the name "Look" in Arabic which later became its specific epithet (Avishai 2017). Deciduous montane woodlands of *Q. look* associated with *Acer monspessulanum* subsp. *microphyllum* constitute a unique habitat endemic to the region, specifically occurring in the region of Mount Hermon. Similar *Q. look* woodlands were also identified at the montane-Mediterranean level on the heights of Mount Barouk in Mount Lebanon (Chouchani et al. 1975; Abi-Saleh and Safi 1988). In this area, this tree species was known to form pure stands within the ecological zone of *Cedrus libani*, sometimes co-dominating with the latter. Nevertheless, these woodlands lacked precise documentation in earlier studies, and this research significantly contributes by providing additional insights into their floral composition. These contributions acknowledge the distinctiveness and rarity of the *Q. look* woodlands.

The floristic complexity of the supra-Mediterranean woodlands was highlighted, revealing two main types distinguished by elevation and the prevalence of either *Quercus coccifera* or *Q. infectoria*. However, the floristic composition did not effectively differentiate between degraded forms of these habitats. For instance, the thickets of *Crataegus azarolus*, representing the degraded form of the upper supra-Mediterranean woodlands of *Q. infectoria*, and the gradual transitions were all grouped together. This emphasizes the crucial role that physiognomy of the vegetation plays in interpreting results.

This brings to light an important parameter affecting the habitats of the western slopes of Mount Hermon, namely the impact of the historical anthropic activities that have gradually modified the physiognomy of the vegetation and thus the landscape of the area. The current landscapes of Mount Hermon are made of relict habitats compared to what they used to be (Abel 1933; Vaumas 1954; Mouterde 1966; Mikesell 1969). For example, the deciduous woodlands of *Quercus look* have almost disappeared and only scattered patches remain in Mount Hermon. The current pastoral activities are not allowing a decent regeneration as the seedlings are systematically grazed by goats.

Similar to many areas in the western slopes of Anti-Lebanon range, the woodlands of *Juniperus excelsa* have disappeared due to intense exploitation for firewood (Mouterde 1966). This was the only conifer species observed in our surveys and it was reported to have a wider distribution in the past. Usually, montane-Mediterranean belts are dominated by coniferous formations (Quézel and Barbero 1982) but it is not the case anymore in Mount Hermon. These woodlands have become rare due to past wood exploitation. The presence of *J. excelsa* woodlands on the western slopes of Anti-Lebanon, between 1,700 and 2,800 m a.s.l. (Vaumas 1954; Mouterde 1966), indicates that the relict

woodlands present on the Lebanese slopes of Mount Hermon could have once extended over a larger area. Historical documents described Mount Hermon with significant forest cover during the antiquity (Abel 1933; Vaumas 1954; Mikesell 1969). Nevertheless, until now it still constitutes the southernmost edge of the distribution range of this conifer (Douaihy et al. 2011, 2013; Caudullo et al. 2017).

Human activities have significantly influenced the diversity at the landscape level, resulting in a characteristic mosaic of vegetation types. This mosaic consists of an alternating succession of grasslands in linear thalwegs with *Q. infectoria* interspersed among rocky hills dominated by *Q. coccifera*. Below 1,500 meters a.s.l., various habitat types bear traces of ancient agriculture. Old terraces, constructed with rocks, are prevalent remnants of agriculture. Often reclaimed by shrubs or trees, these terraces comprise a mix of rocky micro-habitats and grasslands. Another common trace of past agriculture is the presence of rock heaps, remnants of stones cleared for ploughing, mainly located in thalwegs.

The woodlands on Mount Hermon were previously characterised as similar to those on Mount Lebanon, distinguishing them from those of Anti-Lebanon (Abi-Saleh 1982; Abi-Saleh and Safi 1988). However, some typical Mediterranean taxa were absent in Mount Hermon. For instance, in the supra-Mediterranean belt, *Acer obtusifolium*, *Arbutus andrachne*, *Cercis siliquastrum*, *Laurus nobilis*, *Phillyrea latifolia*, and *Pinus brutia* were absent, and similarly, in the montane-Mediterranean woodlands, *Acer hyrcanum* subsp. *tauricola*, *Fraxinus ornus*, and *Ostrya carpinifolia* were also missing. Intriguingly, additional elements have offered insights into floristic affinities between the eastern slopes of Mount Barouk's and the western slopes Mount Hermon. These indications include the absence of certain Mediterranean tree species that are typical of western Mount Lebanon, and the shared presence of the same narrow endemic taxa, namely *Allium feinbergii*, *Bellevalia hermonis*, *Quercus look*, and *Salvia rubifolia* (Mouterde 1966, 1970, 1984).

Conclusion

This study provides the first comprehensive list of plant taxa of the western slopes of Mount Hermon in Lebanon utilizing a habitat-based approach. The significance of elevation, mean annual temperature, slope and northness in shaping the distribution of taxa and habitat types has been demonstrated. The impact of anthropic activities is also an intriguing aspect that should be more frequently quantified and included in studies. However, understanding historical impacts without proper documentation and verified references can be challenging, and the landscapes stand as the last remaining means to decipher the history of the region.

Floristic affinities with Mount Barouk, located in the south part of Mount Lebanon, were highlighted. The analysis of floristic composition allowed the identification and characterisation of ten habitat types: three at the oro-Mediterranean level, hedgehog-heaths of *Astragalus echinus* and *Noaea mucronata* in thalweg and slopes, hedgehog-heaths of *Tanacetum densum and Astragalus cruentiflorus*, cliffs of *Rosularia sempervivum* subsp. *libanotica*, three at the supra-Mediterranean level, namely grasslands with *Eryngium glomeratum*, woodlands of *Quercus infectoria*, *Q. coccifera* and *Crataegus azarolus*, woodlands of evergreen *Q. coccifera*, and four at the montane level, namely scree deciduous woodlands of *Prunus korshinskyi* and *Lonicera nummulariifolia*, woodlands of deciduous *P. korshinskyi* and evergreen *Q. coccifera*, shrublands of *Astragalus gummifer*, deciduous woodlands of *Quercus look* and *Acer monspessulanum* subsp. *microphyllum*. Five novelties can be added to the national typology of habitat as sub-types.

Our research yielded 383 taxa including twenty-four endemics to Mount Hermon and Mount Lebanon, two taxa endemic to Mount Hermon and Anti-Lebanon, and one exclusively endemic to Mount Hermon. It provides a complementary list of taxa for the region. The oro-Mediterranean hedgehog-heath of *Astragalus echinus* and *Noaea mucronata* hosted the highest number of endemic plant taxa (12), followed by the montane woodlands of *Quercus look* and *Acer monspessulanum* subsp. *microphyllum* (10), the scree deciduous montane woodlands of *Prunus korshinskyi* and *Lonicera nummulariifolia* (6), and by montane thalweg deciduous thickets of *Astragalus gummifer* (5). The vulnerability of specific habitat types, particularly *Q. look* woodlands and *Juniperus excelsa* woodlands, as a result of past exploitations, should be considered. This highlights the need for protective measures aimed at conserving these woodlands and enhancing their restoration. Such initiatives could offer dual benefits by preserving the environment and also supporting pastoralist activities that require shaded areas during hot summer days.

Finally, the habitat mapping serves as a valuable tool for visualizing the distribution of habitats and surrounding human activities. It constitutes a crucial resource for the effective management and conservation of the natural heritage. The comprehensive map reveals that the nature reserve on the western slopes of Mount Hermon encompasses the majority of the identified habitats. The insights gained from this study are instrumental in informing the development of a management plan for the nature reserve, ensuring the preservation of its diversity.

Data availability

The data related to the geographic coordinates and elevation, list of observed plant species, and percentage frequency and diagnostic value for each species within each plant community are provided as Suppl. materials 1–4. The entire data are available upon request to the corresponding author.

Author contributions

HE, LC, SB and CK conceptualized the study, carried out the investigation and designed the visualisation of the results. HE conducted the fieldwork and data collection, curated the data, designed the methodology, carried out the analyses, wrote the original draft and took the photographies. LC, SB, CK, DC and MM supervised the study, reviewed and edited the manuscript, were responsible for acquiring funding and were part of the project administration.

Acknowledgements

The authors are grateful to the Observatoire Libano-Francais de l'Environnement (O-LIFE, presently NeoLife) for supporting this work (contribution number SA 15-2022). The authors would also like to acknowledge the "STEPping up Nature Reserves Capacity – STEP4Nature" project funded by the Ministry of Foreign Affairs and International Cooperation of the Italian Republic through the Italian Agency for Development Cooperation (AICS) and implemented by the United Nations Development Programme (UNDP) in coordination with the Ministry of Environment of Lebanon for contributing to field surveys. The authors are thankful to Mehdi Fayeq for accompanying the project team in the field and sharing invaluable information about the area. The authors would like to express their gratitude to Zdeňka Lososová, Idoia Biurrun and the two anonymous reviewers for their valuable remarks, which have contributed to enhancing the quality of this paper.

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Supplementary material

Supplementary material 1
Geographic coordinates, elevation and cluster group of the plots (xlsx).
Link: https://doi.org/10.3897/VCS.106377.suppl1

Supplementary material 2
List of the species observed (pdf).
Link: https://doi.org/10.3897/VCS.106377.suppl2

Supplementary material 3
Full synoptic table with percentage frequency and diagnostic value for each species (pdf).
Link: https://doi.org/10.3897/VCS.106377.suppl3

Supplementary material 4
Full synoptic table with percentage frequency and diagnostic value for each species (*.xlsx).
Link: https://doi.org/10.3897/VCS.106377.suppl4